Earth Science Enterprise Technology Planning Workshop

On-Board Processing

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January 24-25, 2001

Onboard Processing

Focus:

- Technologies needed for data compression, event recognition and response, hyperspectral and radar data onboard processing, and the required processor and memory requirements

Aspects of technology requiring validation:

- Fault-tolerant computing and processor stability
- Autonomous event detection and response
- Situation-based data compression and processing

Earth Science Enterprise Technology Planning Workshop
Onboard Processing

Agenda

Tuesday, Jan 23, 2001

Introduction, Overview	
Real-time earthquake detection	Frank Vernon (UCSD)
On-board architecture	Jason Hyon (JPL)
Recap of the AIST Technology Projection Workshop, August 2000	Loren Lemmerman (ESTO)
Hyperspectral applications	Robert Ferraro (JPL)
Superconducting applications	Jerome Luine (TRW)
Software-implemented fault tolerance	Michael Lovellette (NRL)
Image feature identification	Michael Turmon (JPL)
Autonomous operations	Michael Swartout (Washington Univ)
Radar applications for global precipitation	Eastwood Im (JPL)
Discussion and interim summary of issues	

Wednesday, Jan 24, 2001

Identify convergence of science needs and candidate technology

Define specific capability/technology needs

Identify ongoing investments and development gaps

Formulation of draft technology development roadmaps

flight/ground validation required?

Potential validation missions

Workshop Participants

Name	Affiliation	Name	Affiliation
Aljabri, Abdullah	JPL	Lovellette, Michael	NRL
Allen, Mark	Honeywell	Luine, Jerome	TRW
Andrews, David	U. Kansas	Mills, Carl	LaRC
Barfield, Joe	Southwest Res. Inst.	Minning, Chuck	JPL
Brambora, Cliff	GSFC	Pedersen, Barbara	Computer Sciences Corp.
Brown, Larry Burke, Tom	Motorola Northrop-Grumman	Salay, David Smith, Dan	Battelle General Dynamics
Caprio, Cesare	BAE Systems	Swartwout, Michael	Washington U.
Chu, Kai-Dee Coleman, Tommy	ESTO Alabama A&M	Travler, Ann Turmon, Michael	OSL JPL
Ferraro, Robert	JPL	Vernon, Frank	UCSD
Hyon, Jason	JPL	Wilcox, Jaroslava	JPL
Im, Eastwood Lee III, Robert B.	JPL LaRC	Wood, Kent Wyatt, Jay	NRL JPL
Lindell, Scott	Lockheed-Martin		

Session Approach

- The first day covered:
  - Sample science and mission applications which drive the technology
  - A range of typical technology options for on-board processing
  - Recent results from similar technology workshops
- After the science and technology presentations, session participants developed a list of key topics in on-board processing
- From these topics, a range of potential technology validation experiments/missions was developed

Categories of Onboard Processing Technology Topics

Integrated System Space Test: System-Level Test	No In-space Integrated Systems Test Needed
Autonomy • Communications Node (Standard switched packet node) • Mission Priorities • Science Event Handling • On-Board Resource Management • Autonomous Formation-keeping • On-Board Adaptive Data Management • On-Board Feature Recognition • On-Board Science Decision-Making *Reduce communication bandwidth* *Reduce costs* • Radiation-Tolerant Processors (with Fault Tolerance) • Fault Tolerant Operating Systems for Space Processing • Synchronization *Reduce data latency* • Real-Time Performance *Radical new technology* • MEMS Systems	• Radiation-Hardened Processors • Calibration (Data Handling) • Framework Architecture • Risk Assessment • On-Board Self Tests • Reconfigurable Processor Programming Language • Terrestrial COTS Packages • Low-power Libraries • Memory Technology • Frameworks • Open Source Operating Systems • Data Compression • Data Reduction • Reconfigurable Processors • High-Speed Data Bus (Network Interface Device)

Potential for technology validation missions

- Hardware-related missions:
  - Radiation tolerant processors
  - Communications node (package switching) / radiation tolerant network interface
- Software-related missions:
  - Autonomous spacecraft-level mission operations
  - Payload (instrument-specific) systems

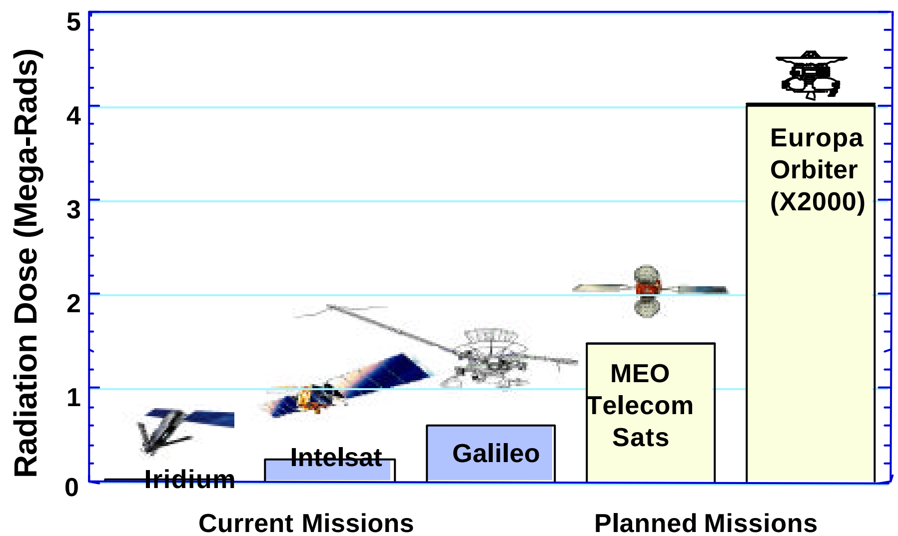
Requirements for:
Radiation Tolerant Processors

The Challenge:

Need radiation tolerance (~100Krad) within one generation of current technology with reliability of rad-hardened

Potential Future ESE Missions:

• **VISION**



Technology Approach:

•Software/hardware augmentation for SEE/SEU susceptibility

•Radiation-tolerant libraries

Drivers for Flight Validation:

•Cannot reproduce space environment on ground

Validation Experiment for:
Radiation Tolerant Processors

Objective:

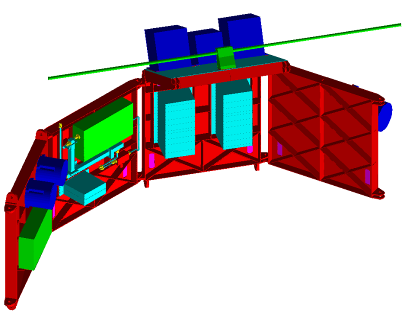
Demonstrate system reliability, quantify improvements

Top-Level Development and Flight Schedule

1. Find "new" hardware (Year 1)
2. Develop fault tolerant operating system (Year 2)
3. Formal ground test (Year 3)
4. Perform space experiment (Year 4)

Scope:

- Piggyback on long-term mission.
- Multiple processors



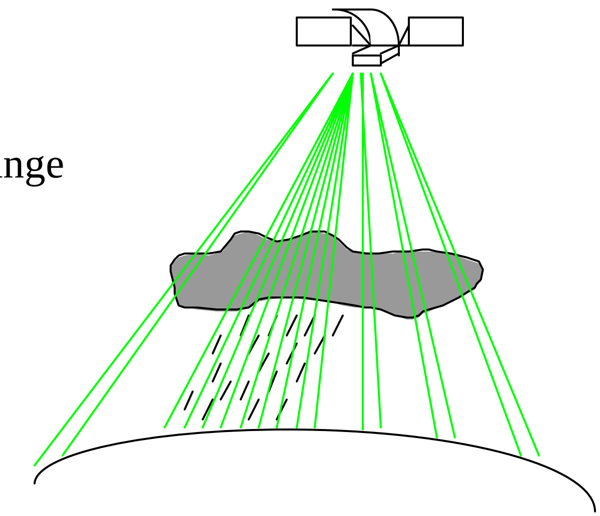
Requirements for:
Communication Node/Radiation Hardened Networks

The Challenge:

•Communications Node/ Radiation tolerant network interface

•Allow common data exchange architecture

•Distributed systems



Potential Future ESE Missions:

- Global precipitation mission
- Any multi-platform mission

Technology Approach:

•Develop common network node to fly on multiple spacecraft

•Develop a packetized, high speed rad-hard data bus

Drivers for Flight Validation:

•Can't reproduce on the ground because of distances and geometry

•Develop high-speed communication components

Validation Experiment for:
Communication Node/Radiation Hardened Networks

Objective:

•Demonstrate a working spaceborne network (packet switching core)
•Demonstrate a standard component interface

Top-Level Development and Flight Schedule

1. Develop network architecture
2. Develop hardware architecture for switching
3. Develop communications architecture
4. Develop Routing software and protocols
5. Fly (would take about 2 years to build)

Scope:

•Piggyback multiple spacecraft/missions

Requirements for:
Autonomy Systems (Spacecraft level)

The Challenge:

(For Planning):

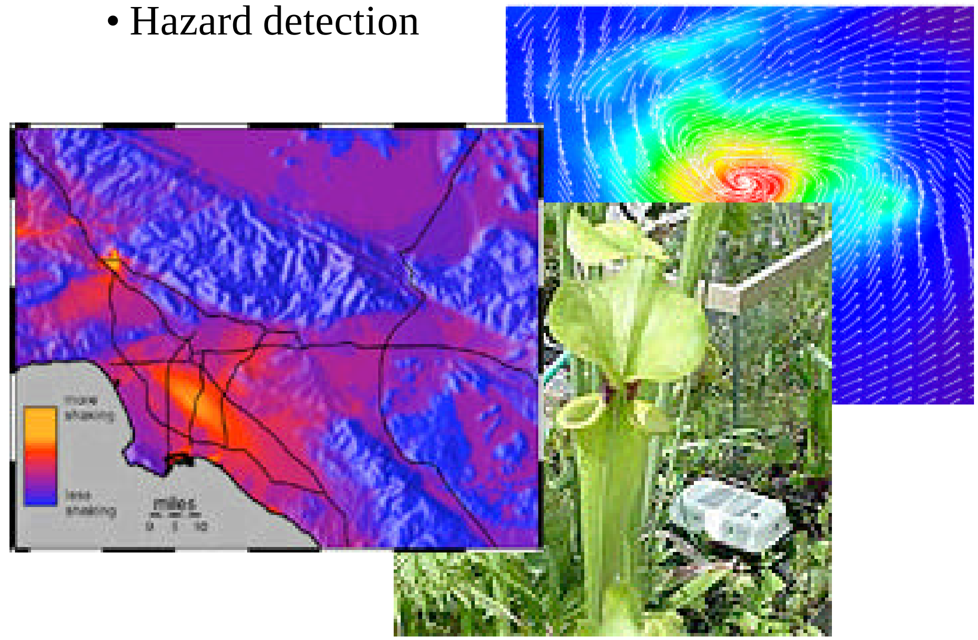
- •Autonomous spacecraft control
- •Software for autonomous mission operations

(For Interesting Targets):

- •Feature extraction

Potential Future ESE Missions:

- Sensor Webs
- Land Cover Inventory
- Hazard detection



Technology Approach:

(For Planning):

- Onboard planning and scheduling
- Synchronization
- Hazard checking
- Resource management
- Event handling

(For Interesting Targets):

- Target handoff
- Region classification
- Template matching
- Model-based identification

Drivers for Flight Validation:

•Long term system level complexity: faults, asynchronous processing, latency

•Target handoff to other spacecraft and instruments

• Ability to use identified features in planning

Validation Experiment for:
Autonomy Systems (Spacecraft level)

Objective:
•Multisensor fusion/web
•Hooked to an incremental planner

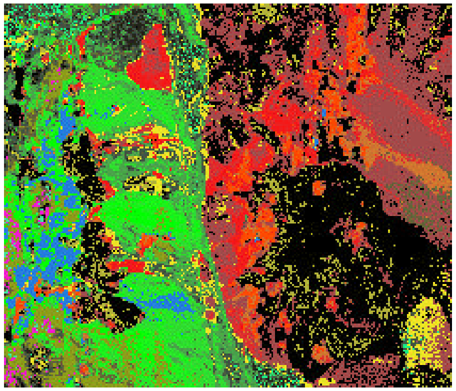
Top-Level Development and Flight Schedule
1. Develop software requirements (Year1)
2. Develop software (e.g., target processing algorithm)
3. Run planner on ground
4. Run piggyback mission
5. Run multi-spacecraft mission (2005 timeframe)

Scope:
•Value-added multiple sensor mission
•Could be dedicated or piggyback

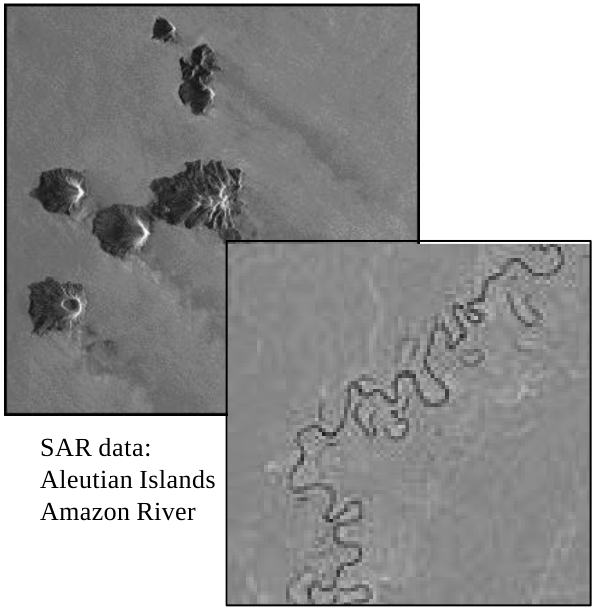
Requirements for:
Payload Systems (instrument specific)

The Challenge:
•Data reduction
•More effective bandwidth utilization
•Fault tolerant and robust

Potential Future ESE Missions:
• Hyperspectral instruments
• Large data intensive systems (SARs)



AVIRIS data:
Mineral map,
Cuprite, Nevada



SAR data:
Aleutian Islands
Amazon River

Technology Approach:
Develop common packages for
- •data compression
- •Fourier transforms
- •selection and segmentation

Drivers for Flight Validation:
•Validate fault models, reliability, accuracy
•Scientific acceptance: demonstrate robustness

Validation Experiment for:
Payload Systems (instrument specific)

Objective:

•Demonstrate advanced fault-tolerant software
•Dramatic reduction in downlink bandwidth or increased use of existing link
•Quantify and enable new science - 10x or more

Top-Level Development and Flight Schedule

1. Science collaboration
2. Could fly soon - new hardware development not necessary

Scope:

•Value-added to appropriate missions (hyperspectral, Firesat)
•Could be piggyback

Summary Tables

TECHNOLOGY DESCRIPTION			VALIDATION EXPERIMENT			
Future Mission Type (ESE Mission applicability)	**Challenge Description**	**Technology Approach**	**DRIVER(S) FOR FLIGHT VALIDATION**	**OBJECTIVE**	**SCOPE**	**MILESTONES**
VISION	Need radiation tolerance (~100Krad) within one generation of current technology with reliability of rad-hardened.	Software/hardware augmentation for SEE/SEU susceptibility	Cannot reproduce space environment on ground	Demonstrate system reliability, quantify improvements	Piggyback on long-term mission. Multiple processors.	1. Find "new" hardware (Year 1) 2. Develop fault tolerant operating system (Year 2) 3. Formal ground test (Year 3) 4. Perform space experiment (Year 4)
		Radiation-tolerant libraries	none			
Global Precipitation Mission, any multi-platform mission	Communications Node/ Rad tolerant network interface	Develop common network node to fly on multiple spacecraft	Can't reproduce on the ground because of distances and geometry	Demonstrate a working spaceborne network (packet switching core)	Piggyback multiple spacecraft/missions	1. Develop network architecture 2. Develop HW architecture for switching 3. Develop comm architecture 4. Develop Routing SW/protocols 5. Fly (2 years to build)
	Allows common data exchange architecture Distributed	Develop a packetized, high speed rad-hard data bus	Develop high-speed communication components	Demonstrate a standard component interface	Any host mission - (piggyback)	same as above

Summary Tables (Cont.)

TECHNOLOGY DESCRIPTION			VALIDATION EXPERIMENT			
Future Mission Type (ESE Mission applicability)	**Challenge Description**	**Technology Approach**	**DRIVER(S) FOR FLIGHT VALIDATION**	**OBJECTIVE**	**SCOPE**	**MILESTONES**
Sensor Webs, Land Cover Inventory, Hazard detection (earthquake, buoys)	(Planning) Autonomous spacecraft control; SW for autonomous mission operations	Onboard planning scheduling, synchronization, hazard checking, resource management, event handling	Long term system level complexity, faults, asynchronous processing, latency	Multisensor fusion/web; hooked to an incremental planner	Value-added multiple sensor mission (could be dedicated or piggyback)	1. Develop SW requirement (Year1) 2. Develop SW (e.g., target processing algorithm) 3. Run planner on ground 4. Run piggyback mission 5. Run multi-SC mission ['05 timeline]
	(Interesting targets) Feature Extraction	Target handoff, region classificaton, templated matching, model-based	Target handoff to other spacecraft and instruments. (Instrument specific). Ability to use identified features in planner in previous line).			
Hyperspectral instruments, large data intensive systems (SARs) [SW-instrument]	Data reduction, more effective bandwidth utilization, fault tolerant and robust	Develop common packages for data compression and Fourier transforms, selection and segmentation	Validate fault models, reliability, accuracy. Scientific acceptance: demonstrate robustness	Demonstrate advanced fault-tolerant software. Dramatic reduction in downlink bandwidth or increased use of existing link. Quantify and enable new science - 10x or	Value-added to appropriate missions - hyperspectral, Firesat. Could be piggyback.	1. Science collaboration. Could fly soon - new hardware development not necessary.